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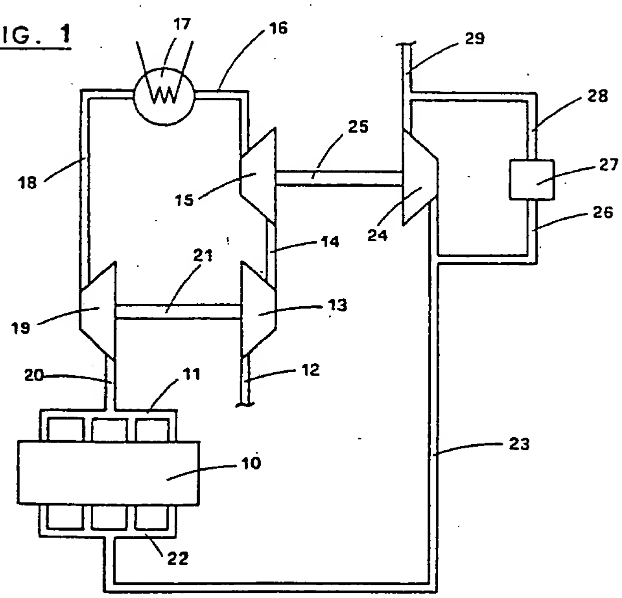
(54) Supercharger system for an internal combustion engine

(57) An internal combustion engine having a turbo charger 15, 24 is rendered more efficient by a supercharging system, in which the compressed air is cooled by successive passage through a heat exchanger 17 and an expansion turbine 19, and in which the work obtainable at the turbine shaft is utilised for supplementary air compression by compressor 13.

FIG. 1



The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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FIG. 1

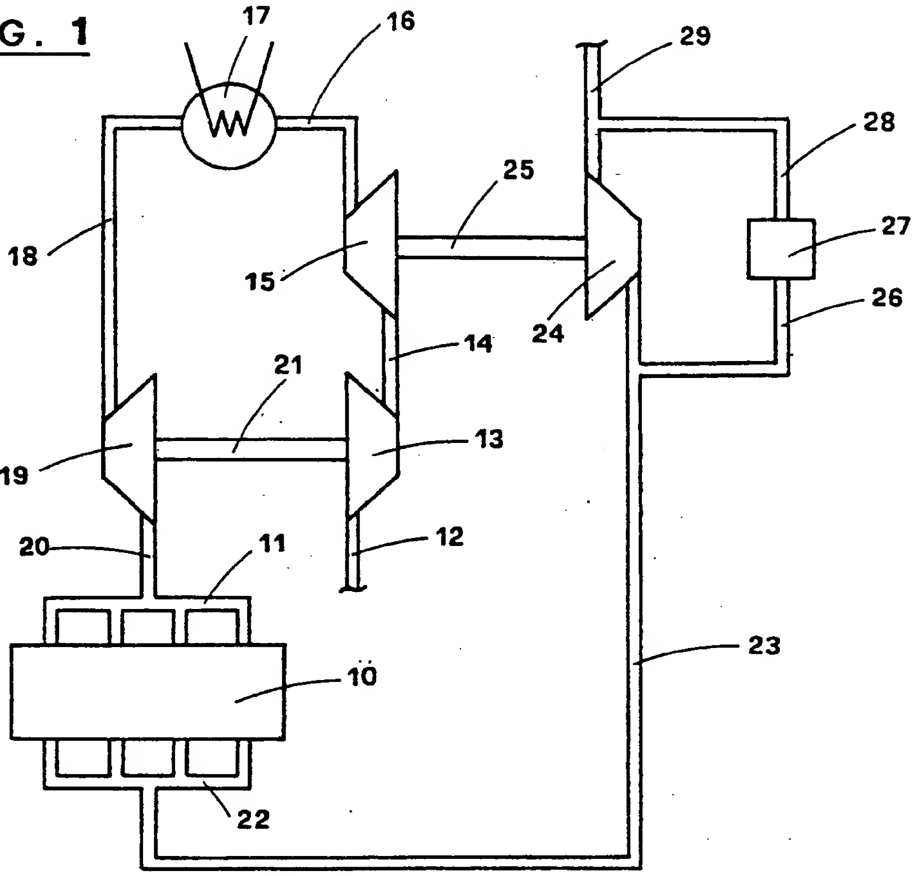
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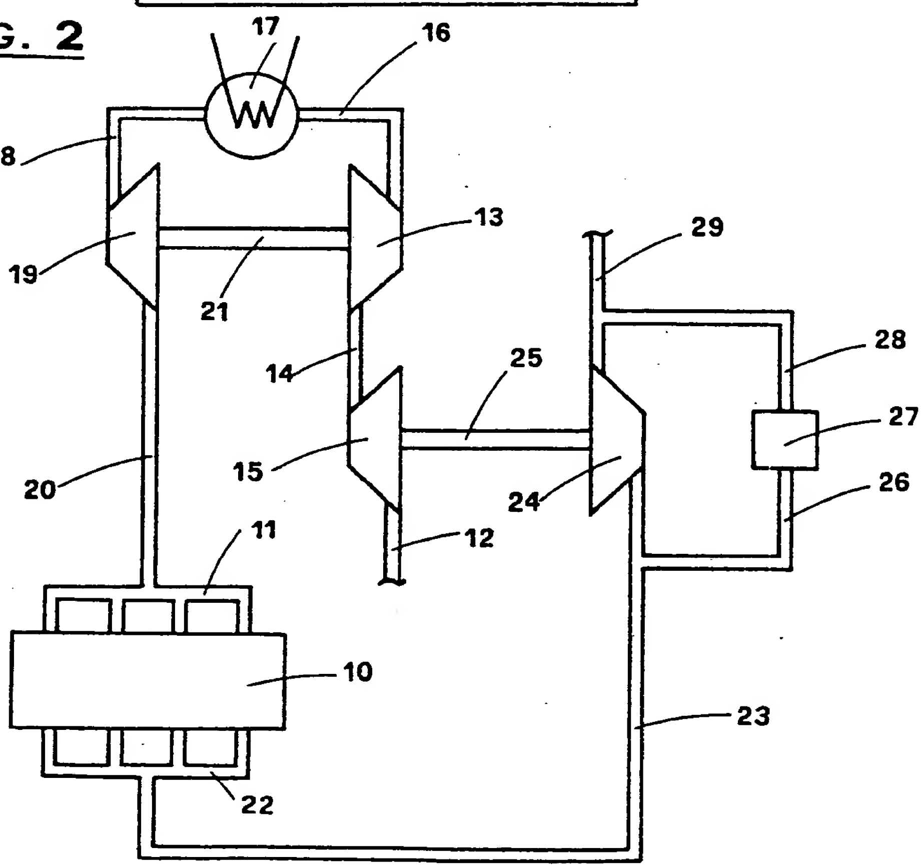
FIG. 2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SPECIFICATION

Supercharger system for an internal combustion engine

One of the methods most commonly used for increasing the power delivered by an internal combustion engine is supercharging, attained by volumetric or centrifugal compressors.

The supercharging efficiency depends on the density increase which the air undergoes by the effect of the compression, and is higher the greater the density.

However, the density increase is accompanied by a moderate temperature increase which in controlled ignition engines leads to the danger of detonation. Its prevention requires a reduction in the volumetric compression ratio, leading to an increase in fuel consumption at low engine loads.

This means that the air has to be cooled before feeding it to the cylinders.

In most cases, the air is cooled before its entry to the cylinders by means of heat exchangers of the air-air or air-water type, but these methods are of limited efficiency because they do not allow the superchanger air to be greatly cooled due to the fact that the temperature of the cooling fluid is at best equal, and not less than, ambient temperature.

These methods also result in overall sizes which are greater the larger the heat exchanger cooling capacity, as heat transfer increases with the heat exchange surface area for a given temperature difference.

To overcome the limitations of these methods without using very complex constructions, a supercharger system for an internal combustion engine is provided in which the compressed air is cooled to a certain extent in a heat exchanger, and is then subjected to partial, substantially adiabatic expansion in a turbine in which it is strongly cooled to a temperature equal to or less than ambient, the temperature change being a function of the pressure difference across the turbine. A substantial characteristic of the invention is that the work obtainable from the turbine is used for driving a supplementary compressor which further compresses the air, adding its own action to that of the normal compressor which is operationally connected to the engine.

This means that the compressor operationally connected to the engine does not have to be operated under more critical conditions to obtain the same head, or alternatively that constructionally complex methods such as several compression stages operationally connected to the motor are not necessary.

The supercharger system thus provided comprises at least one air intake duct provided with first air compressor means operationally connected to the internal combustion engine, and heat exchanger means which partially cool the air and are disposed downstream of said first compressor means, and is characterised by further comprising at least one turbine in which the air undergoes partial expansion and disposed downstream of said heat exchanger means, and second air compressor means disposed upstream of said heat exchanger means and operationally connected to said turbine.

The fuel necessary for forming the mixture can be delivered by an injection system, whether the fuel is petrol or diesel oil, or can be supplied by carburettors preferably disposed downstream of said heat exchanger.

One embodiment of the supercharger system according to the invention is shown diagrammatically in Figure 1, and a modification thereof is shown in Figure 2.

In Figure 1, the reference numeral 10 indicates a multi-cylinder internal combustion engine which is fed with air or with a mixture of air and fuel through the intake manifold 11. The engine feed air, possibly after filtration, passes through the intake duct 12 and into the centrifugal compressor 13, and from here passes through the intake duct portion 14 and into the centrifugal compressor 15. The compressed air passes through the intake duct 16 and into the heat exchanger 17, for example of the air-air type, where it loses part of the heat acquired in the compressors 13 and 15 by the effect of the substantially adiabatic compression.

The air passes through the intake duct 18 to a centripetal turbine indicated by 19, where it undergoes partial substantially adiabatic expansion, with consequent strong cooling which brings it to a temperature equal to or less than ambient, the temperature at the end of expansion being a function of the pressure difference across the turbine.

The air leaving the turbine 19 passes through the intake duct 20 and into the manifold 11, and then to the cylinders of the engine 10.

Groups of engine cylinders could obviously be fed separately by using a supercharger system of the described type for each group of cylinders.

As shown in the Figure, the compressor 13 is driven by the turbine 19 by way of the shaft 21, and thus utilises the work produced by the partial expansion of the air in said turbine.

In the illustrated example the compressor 15 is driven by the shaft 25 from a centripetal turbine 24 operated by the engine exhaust gas.

The engine exhaust gas enters the manifold 22, and from here reaches the turbine 24 through the duct 23. Part of the exhaust gas passes into the short-circuiting duct 26 when the pressure in the manifold 11 exceeds a predetermined threshold value, and provided the valve 27 is open.

This exhaust gas flows through the duct 28 and into the exhaust pipe 29, which leaves the turbine 24.

By means of the described system, efficient cooling of the pressurised air feeding the engine is obtained by the subtraction of heat in the heat exchanger 17 and the subsequent expansion in the turbine 19.

The pressure and thus the density of the air at

the cylinder inlet can be kept at the design values without strongly increasing the capacity of the compressor 15, because part of the pressure drop undergone by the air through the turbine 19 is compensated by the pressure increase upstream attained by the supplementary compressor 13.

These results have been verified by calculation for various system configurations.

Assuming a centrifugal compressor 15 capable of a compression ratio λ_c of 3, a heat exchanger 17 having an efficiency η of 0.8 and an ambient air temperature t_e of 27°C, then in the case of a system without the turbine 19 and compressor 13, a compressed air temperature at the cylinder inlet T_a of 58°C was obtained, with an air density δ of 0.325 kg_m/m^3.

In contrast, using a centrifugal compressor 15 capable of a compression ratio λ_c of 4, a centrifugal compressor 13 with a compression ratio λ_{cs} of 1.7 and a turbine 19 with a pressure ratio λ_T of 2.5, a compressed air temperature at the cylinder inlet T_a of 22°C was found, with an air density δ of 0.333 kg_m/m^3.

Thus practically the same engine supercharging was obtained, as the air densities were substantially equal, but with a considerable difference in the feed temperature, namely 58°C against 22°C.

If the compressor 13 had not been provided, than a turbocompressor 15, possibly of the multi-stage type, would have had to have been used capable of alone providing the overall compression ratio of 4x1.7, ie 6.8.

The supercharger system shown in Figure 2 comprises the same components as that of Figure 1, and the same reference numerals have therefore been used for indicating them.

The two systems also operate identically, the only constructional difference being the arrangement of the compressor 13, which in the second case is downstream of the compressor 15.

Claims

1. A supercharger system for an internal combustion engine, comprising at least one air intake duct provided with first air compressor means operationally connected to said engine, and heat exchanger means which partially cool the air and are disposed downstream of said first compressor means, and characterised by further comprising at least one turbine in which the air undergoes partial expansion and disposed downstream of said heat exchanger means, and second air compressor means disposed upstream of said heat exchanger means and operationally connected to said turbine.

2. A system as claimed in claim 1, characterised in that said second compressor means are constituted by a centrifugal compressor disposed in said engine intake duct upstream of said first compressor means.

3. A system as claimed in claim 1, characterised in that said second compressor means are constituted by a centrifugal compressor disposed in said engine intake duct downstream of said first compressor means.

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